Advancing the adoption of artificial nitrogen sinks

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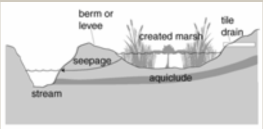
Introduction

Constructed wetlands and denitrifying bioreactors are artificial "sinks" (hotspots of N removal) that are created to resemble natural systems that promote denitrification. When installed at the edge of an agricultural field, they can intercept groundwater or tile drainage water and reduce the nitrate-N content of agricultural discharge. The goal of our project is to advance the adoption and proper placement of denitrifying bioreactors and constructed wetlands in agricultural settings.

Constructed Wetlands

Constructed wetlands (Fig.1) are artificial systems that provide ecological services, such as flood water storage, nutrient (nitrogen or phosphorus) storage and cycling, and erosion control. They are modeled after natural wetland systems. These systems are placed alongside ditches or streams where they retain water for hours or days to allow nitrate-N removal through denitrification.

Figure 1: Conceptual diagram of constructed wetland treating tile drainage (Mitsch and Day 2006)



Denitrifying Bioreactors

A denitrifying bioreactor (Fig.2) is an artificially constructed system that mimics selected functions of riparian wetlands. These systems are composed of an added source of carbon (often woodchips) that intercept groundwater or tile drainage. The wood chips create an anaerobic environment in which bacteria transform the nitrate-N in the water into nitrogen gas.

Figure 2: Denitrifying Bioreactors

The two main types of denitrifying bioreactors are beds (Fig. 2a) and walls (Fig. 2b). Beds are closed systems that receive tile drain inflow. Walls are placed in the natural flowpath of groundwater leaving from agricultural fields.

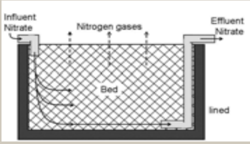


Fig 2a: Denitrification bed to treat tile drainage (Schipper et al. 2010)

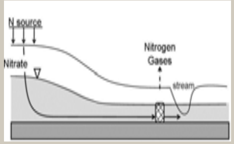


Figure 2b: Denitrification wall to intercept groundwater flow (Schipper et al. 2010)

Outreach Approach

www.artificialnsinks.org

This website, primarily targeting land managers and farm advisors, offers guidance, an International Atlas of constructed wetlands and denitrification bioreactors, fact sheets, case studies, presentations, videos and other resources.

We also have a listserv to share news on artificial N sinks and share project successes. To join our listserv, email kaddy@uri.edu.

The International Atlas identifies artificial N sink research and demonstration sites from across the globe. The map not only gives information about where the systems are but also provides project contact information, links to case studies, papers, and websites with additional information. We welcome any additions to our atlas or website (email kaddy@uri.edu).

Resources include fact sheets, case studies, videos, workshop presentations and research summaries about constructed wetlands and denitrifying bioreactors. Research papers written by scientists are further studied and condensed into summaries in our case study section which highlights the situation, actions, and take-home messages. We also have videos and fact sheets that highlight similar subject matter.

Another important feature of the website is the **Frequently Asked Questions (FAQs)** which provides basic information on the function and processes of artificial N sinks. Basic information about point source pollution, dead zones and other related details are also present on this page. Most questions have links to EPA definitions and videos which give a fuller understanding of the subject.

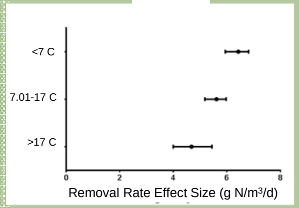
Meta-analysis Approach for Denitrifying Bioreactors

Meta-analysis: Methods

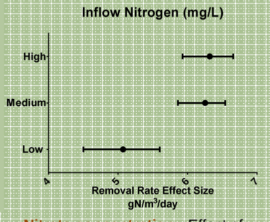
Meta-analysis is a tool for quantifying trends across systems characterized by different summary statistics. We used MetaWin version 2.1 software (Rosenberg et al. 2000) to compare nitrate-N removal rates in denitrifying bioreactors across different classes of temperature, inflow nitrate-N, and retention time. Mean effect sizes were considered significantly different if their 95% CIs were non-overlapping.

Studies used in meta-analysis	Location	Temp	Inflow N	Retention Time
Cameron & Schipper 2010	Laboratory	X	X	X
Cameron & Schipper 2011	New Zealand	X	X	X
Christiansen et al. 2011ab, 2012	Iowa	X	X	X
Chun et al. 2009	Laboratory	X	X	X
Elgood et al. 2010	Ontario	X	X	X
Gibert et al. 2008	Laboratory		X	X
Greenan et al. 2006, 2009	Laboratory	X	X	X
Healy et al. 2012	Laboratory	X	X	X
Jaynes et al. 2008	Iowa		X	
Long et al. 2011	New Zealand	X	X	
Robertson & Cherry 2005	Ontario			X
Robertson et al. 2000	Ontario	X		
Robertson et al. 2009	Ontario			
Robertson et al. 2010	Laboratory	X	X	X
Schipper et al. 2000	New Zealand	X		
Schipper et al. 2005	New Zealand	X	X	X
Schipper et al. 2010a	New Zealand	X	X	
Schipper et al. 2010b	New Zealand		X	
Schmidt & Clark 2012	Florida	X	X	X
Warneke et al. 2011ab	New Zealand	X	X	
Warneke et al. 2011c	Laboratory	X	X	

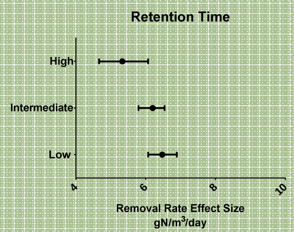
Meta-analysis: Initial Results



Temperature: Effect of temperature on nitrate-N removal rate is significant between the low and high categories with higher removal at higher temperatures.



Nitrate concentration: Effect of inflow nitrate-N concentration on nitrate-N removal is significantly different between low N and both intermediate and high N.



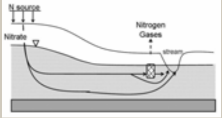
Retention time
There was no significant effect of retention time on nitrate-N removal.

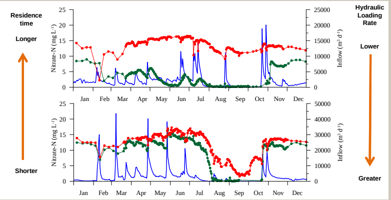
Some magnificent thoughts to go here

….(please note that the forest plots need to specify the actual ranges of N conc and time and have similar formating)

Limitations & Next Steps

Artificial N sinks are not suitable for all locations and conditions. It is important to consider site conditions and hydrology at all sites to maximize N removal function.





Flowpaths: If a denitrifying bioreactor is intended to intercept natural groundwater flow, site hydrology must be understood. For instance, deep groundwater flow can bypass treatment. (Schipper et al. 2010)

Residence time and hydraulic loading: For high N removal in both constructed wetlands and denitrifying bioreactors, longer residence times need to be accommodated when hydraulic loading is high. (Crumpton, ISU)

Cost and Social Barriers to adoption are other important limitations for artificial N sinks.

Next Steps

- Continue meta-analysis to refine our synthesis of controlling factors and recommendations
- Explore geospatial data for improved siting of artificial N sinks
- Assess potential adverse effects: greenhouse gases, dissolved organic carbon, and methyl mercury

Acknowledgements & References

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